Design of a Multi-Pass Extraction Architecture for the DiPOLE Prototype Amplifier

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Science & Technology Facilities Council
Central Laser Facility

Requirements

- A multi-
  for the
- Betwee
  efficien
  with mi
- Relay-i
  - Main
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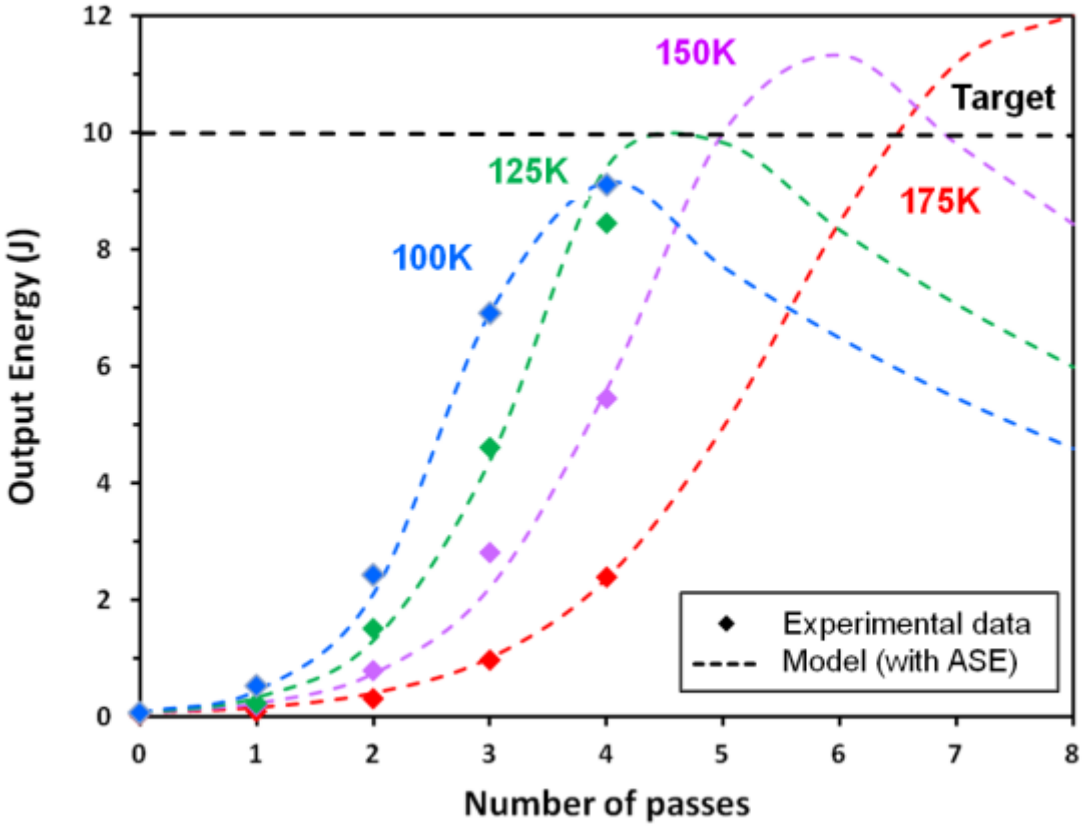
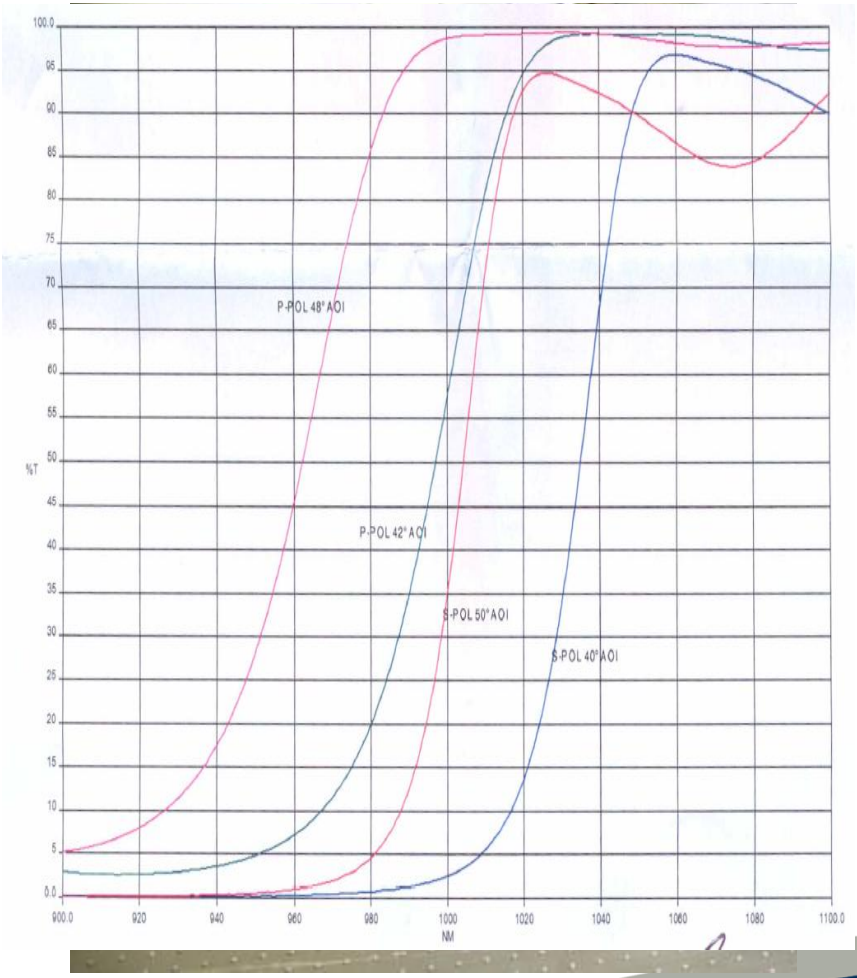
  - Effici
- Spatial
  - Maintain good beam quality
  - Minimise risk of hotspots & optical damage



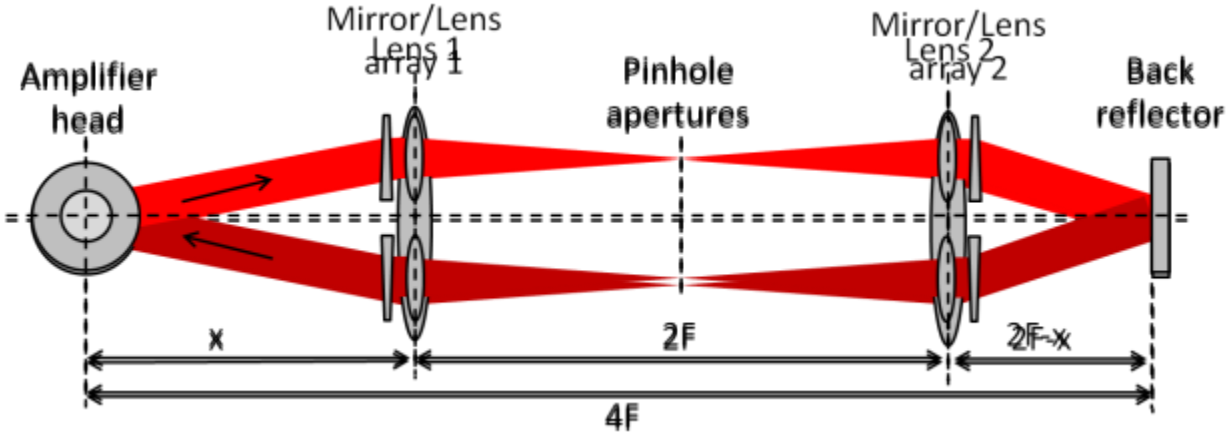
Constraints

- Limited space available on optical table(s)
- Dichroic polarising beamsplitters for pump coupling
  - HR at 940nm (s-pol)
  - HT at 1030nm (p-pol)
  - Limited angular acceptance ± 3° for 1030 nm (p-pol)
- Beam size within amplifier
  2 cm x 2 cm square
- Angular multiplexing most appropriate solution



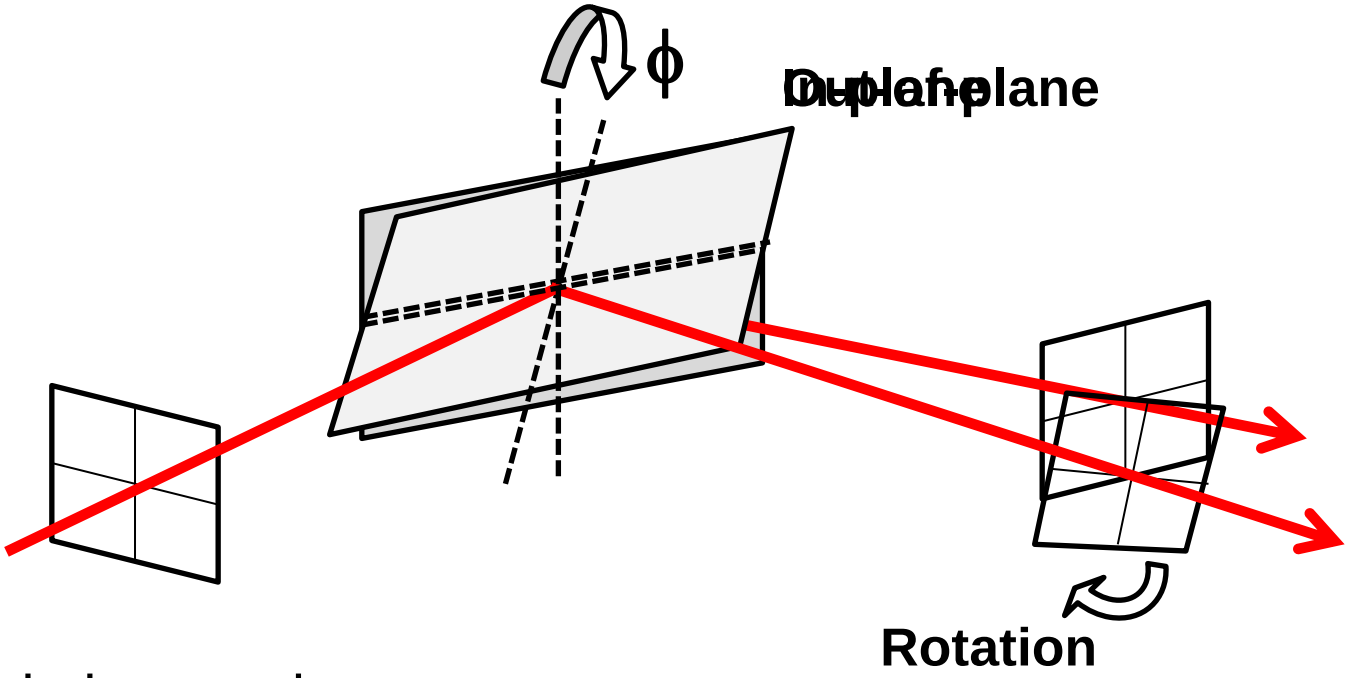
Relay Imaging System

- DiPOLE 4F relay system



- Replace large lenses with lens and steering mirror arrays
  - Ensures beams propagate on-axis to minimise aberrations
- Two independent relay imaging telescopes for each pass
  - Independent alignment & flexibility in beam propagation direction
  - Predictable pinhole position
- Turning mirrors lead to folded geometry
  - Helps fit DiPOLE space constraints

Geometrical Considerations



- Minimise rotation
- Reflection out of the plane perpendicular to the rotation axis of the steering mirror
  - Ensure out of plane reflections only occur in longer (2F x) sections
  - Beam & polarisation axis rotate about propagation axis
  - Significant if out-of-plane angle ϕ large i.e. for asymmetric designs where x << F

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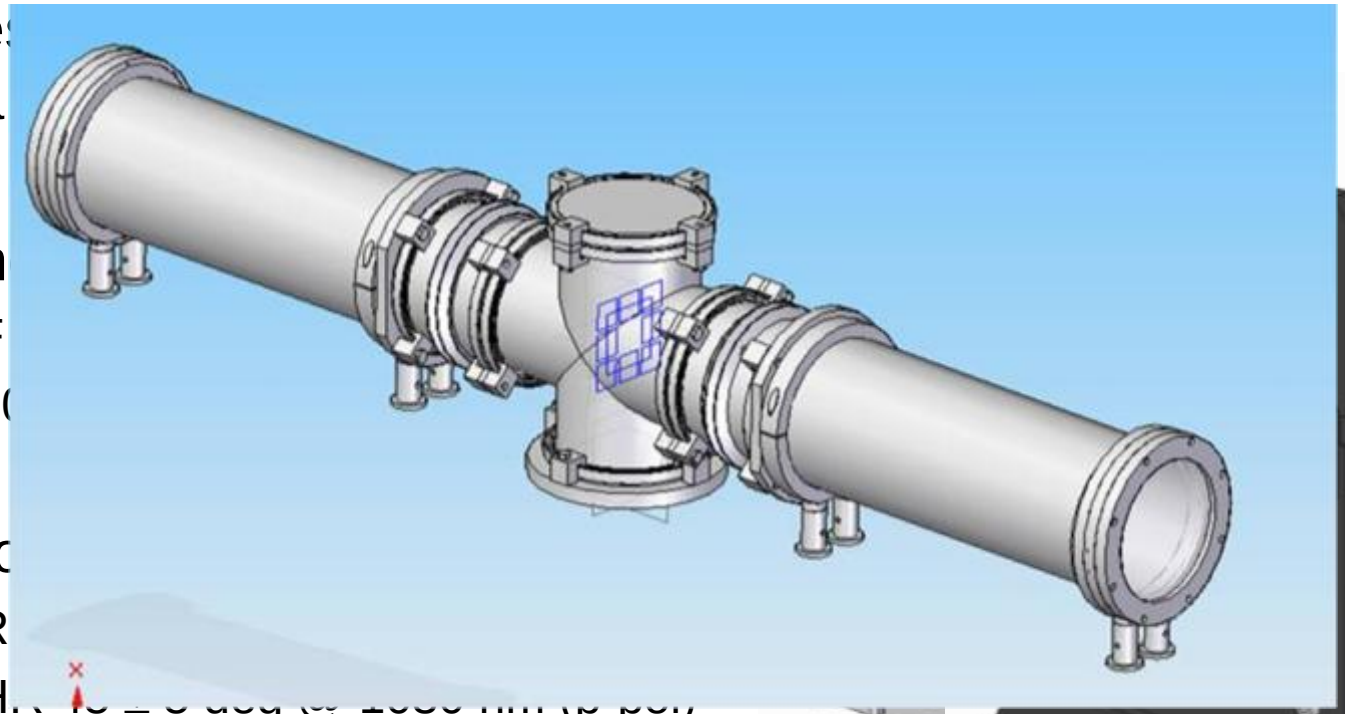
  - Ensure out of plane reflections only occur in longer (2F x) sections where x << F (< 5 deg)
  - Keep multiplexing angle as small as possible
    - Keep lens / mirror array pitch size as small as possible
    - Use square lenses / rectangular mirrors for closer packing

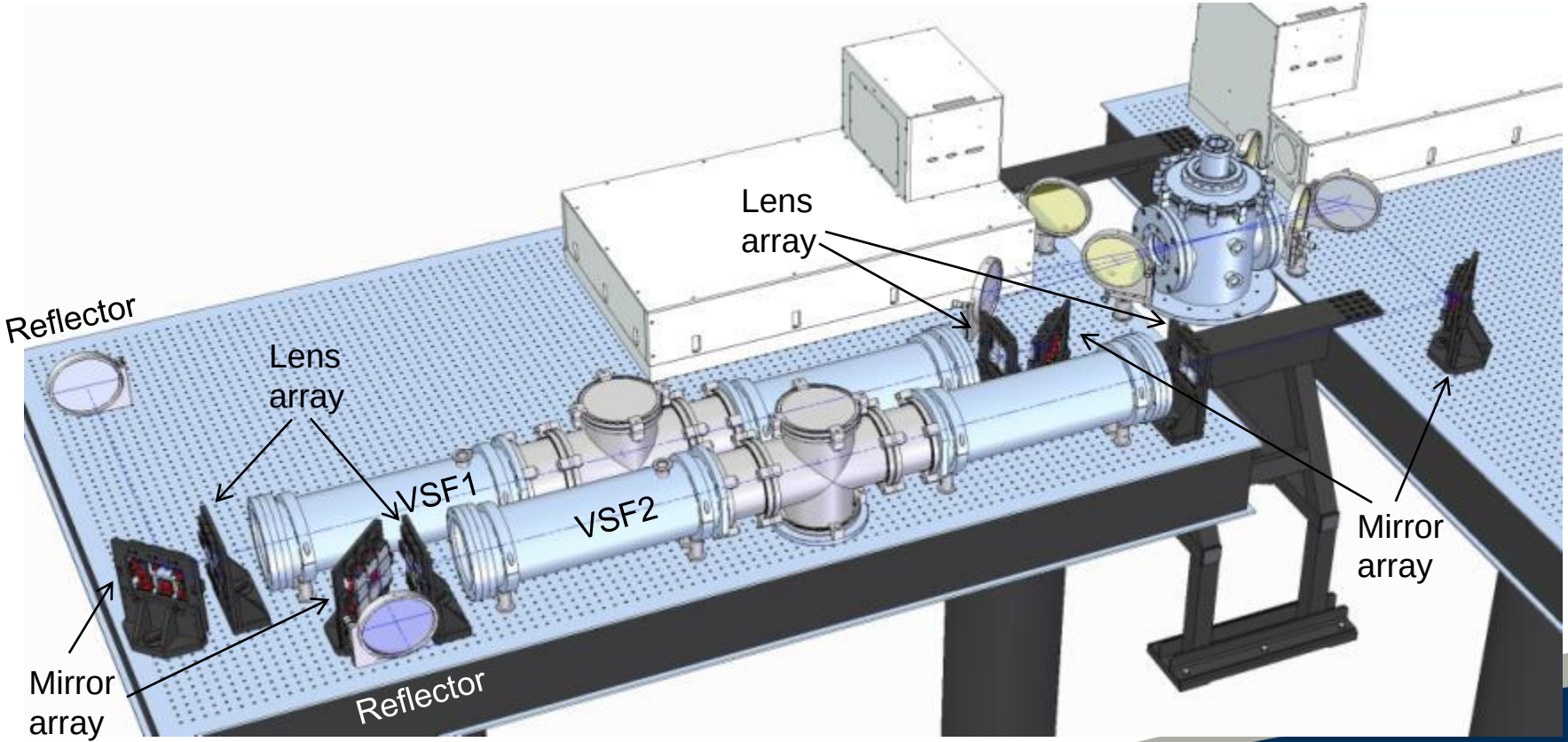
Telescope Design

- Tele
  of a
- Plan
  - F
  - 3
- Mirro
  - R
  - H
- Vacuum spatial filters
  - Each VSF has 8 independent & adjus

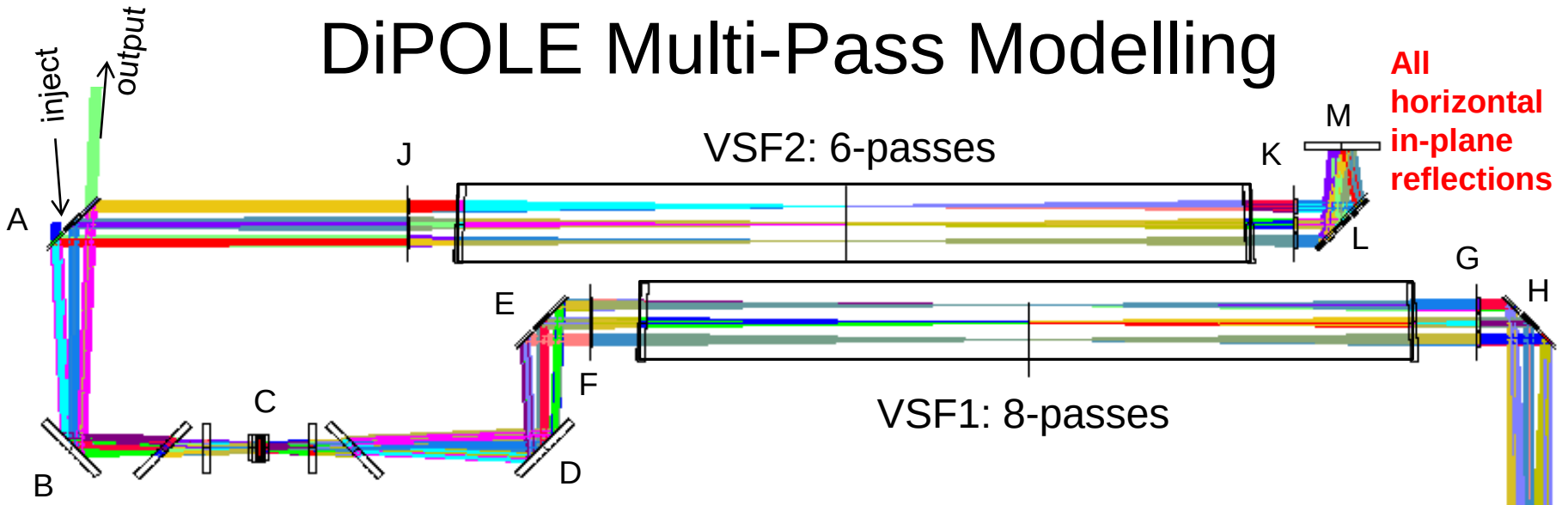


DiPOLE Multi-Pass Design

- Asymmetric design chosen because of space constraints
  - Z-folded geometry ensures path lengths are similar for all passes

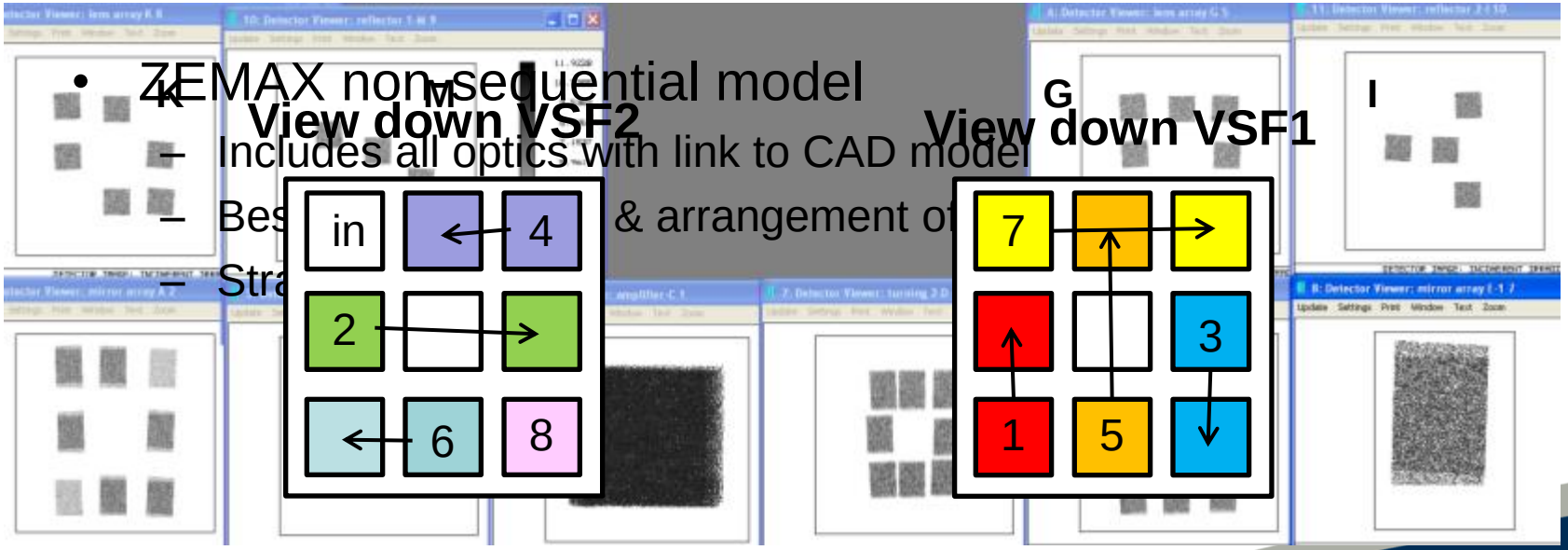


DiPOLE Multi-Pass Modelling



All horizontal in-plane reflections

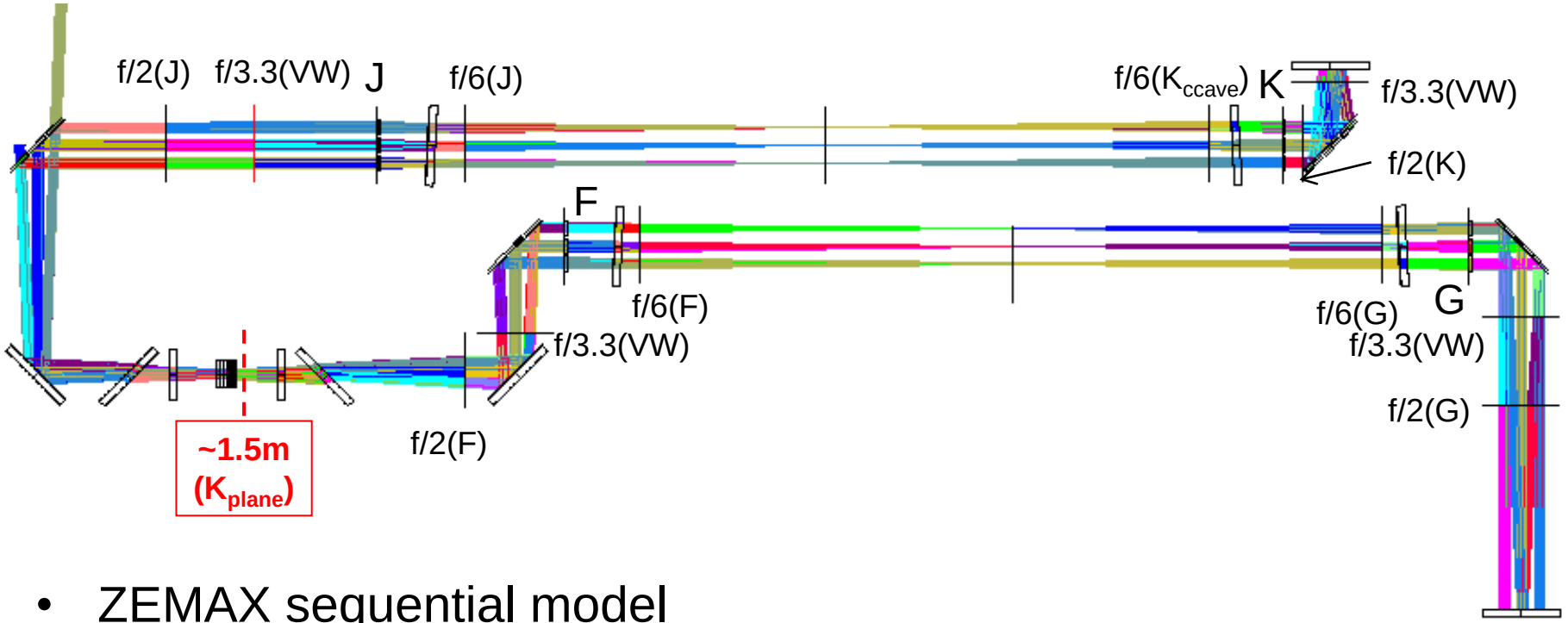
- ZEMAX non-sequential model
  - Includes all optics with link to CAD model
  - Bes & arrangement of
  - Stra



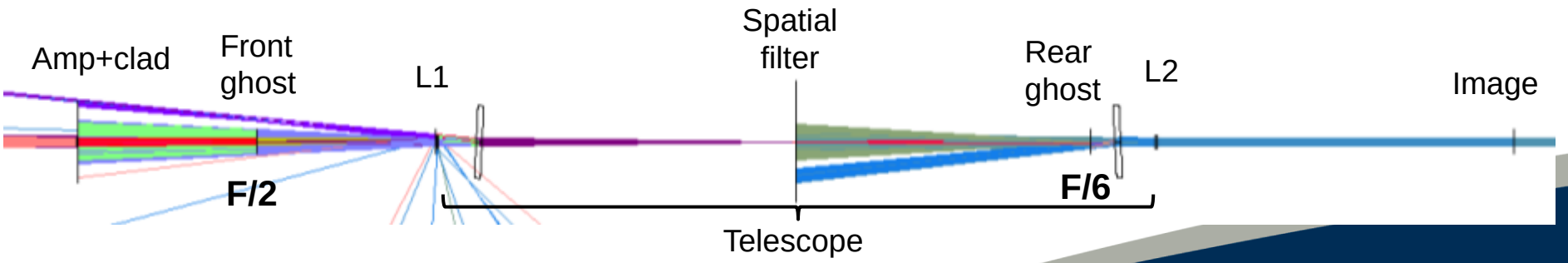
All vertical out-of-plane reflections

A B AMP D E

Primary Ghost Foci Positions

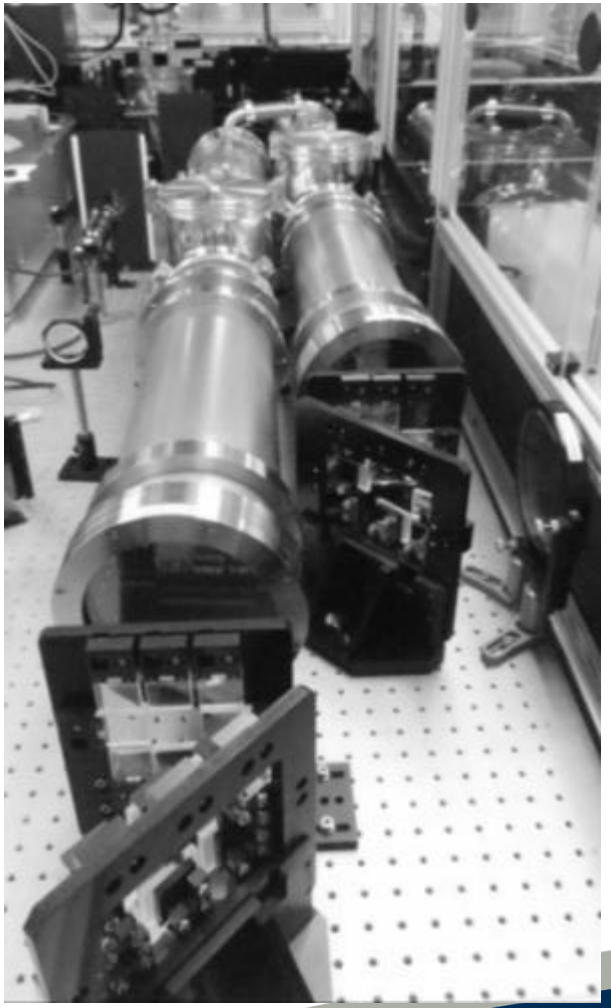


- ZEMAX sequential model



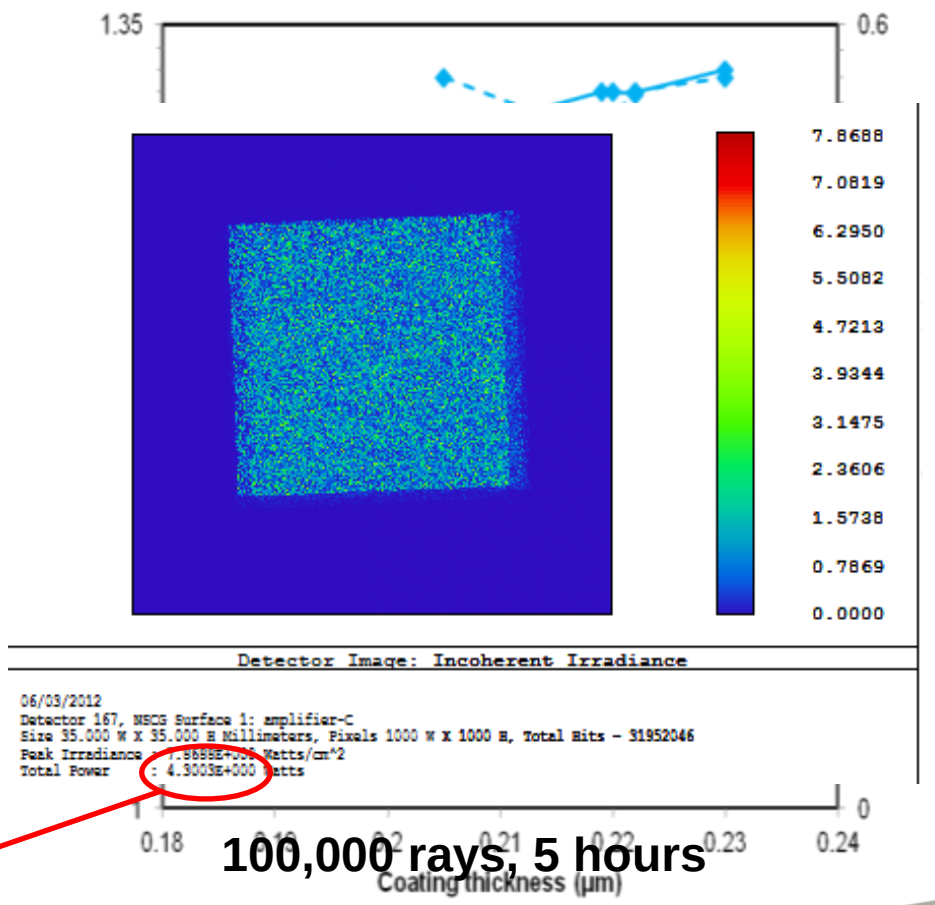
Build & Testing

- Manufacture of system components commenced June 2011
  - All optics supplied by CVi IoM
  - Custom mirror array mounts from Radiant Dyes Laser, Germany
- Installation completed June 2012
- Upgraded ZEMAX non-sequential model
  - Full stray light analysis with all system components, VSFs etc.
  - Gain in amplifier, ensure rays are maintained & provide estimate of fluence levels



Modelling GAIN in ZEMAX

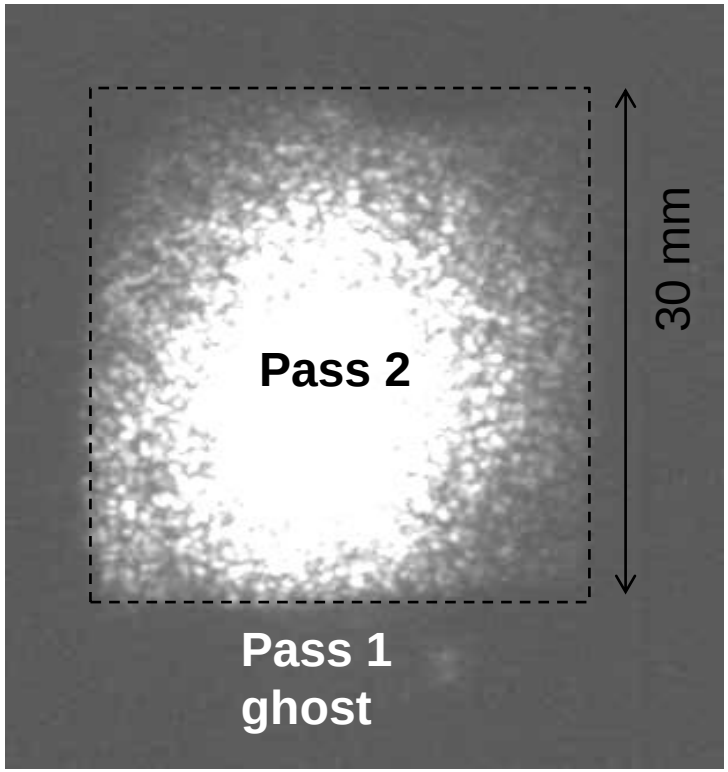
- Target gain per pass (G_o)
  - $G_o = (E_{out}/E_{in})^{1/passes}$, passes=4
  - E_{in} = 0.1 J, E_{out} = 10 J, G_o = 3.16
- Target gain per disk (G_d)
  - $G_d = G_o^{1/disks} = 1.33$
- Add disk coating with (+)ve extinction coefficient (k)
- Coating design
  - Index 1.39 ~ $\sqrt{n_{YAG}}$ (1.81)
  - Optical thickness 0.22 µm ~ quarter wave
  - Reasonable AR coating ~0.5% R
- ZEMAX model
  - E_{out} = 4.5 J



100,000 rays, 5 hours

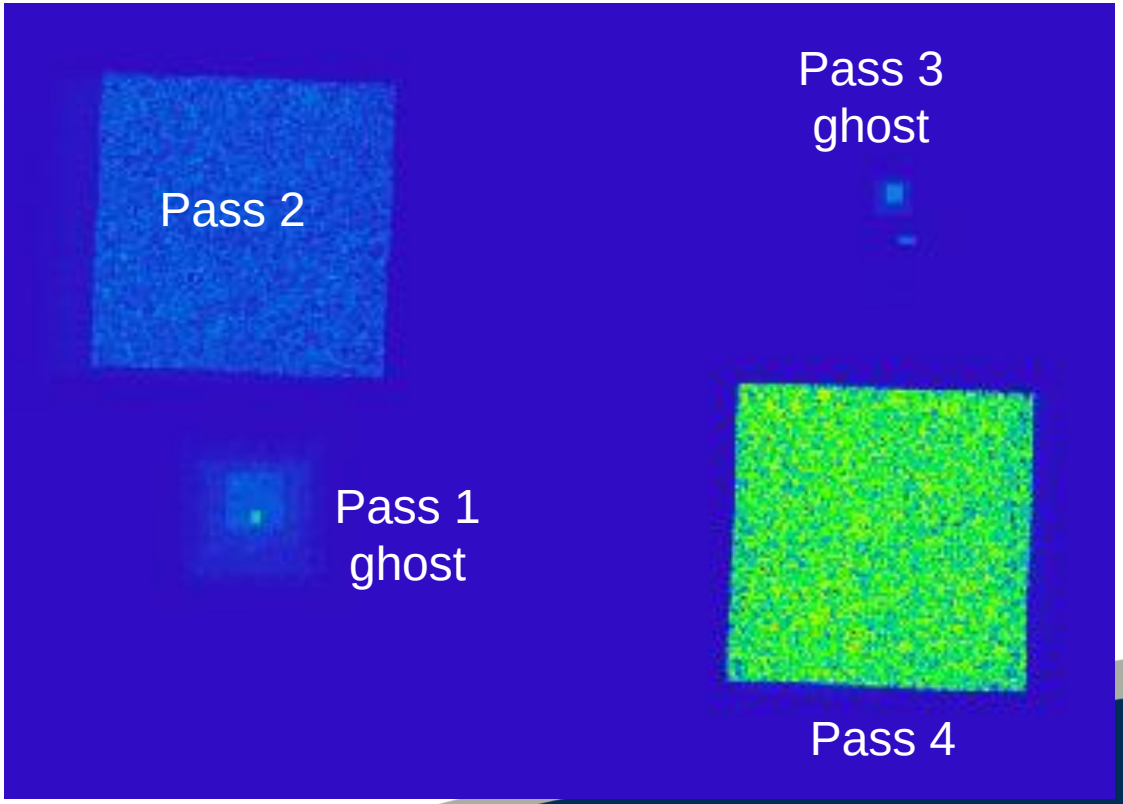
Ghost Predictions

- Primary ghost foci F/2 from plane face of lens F



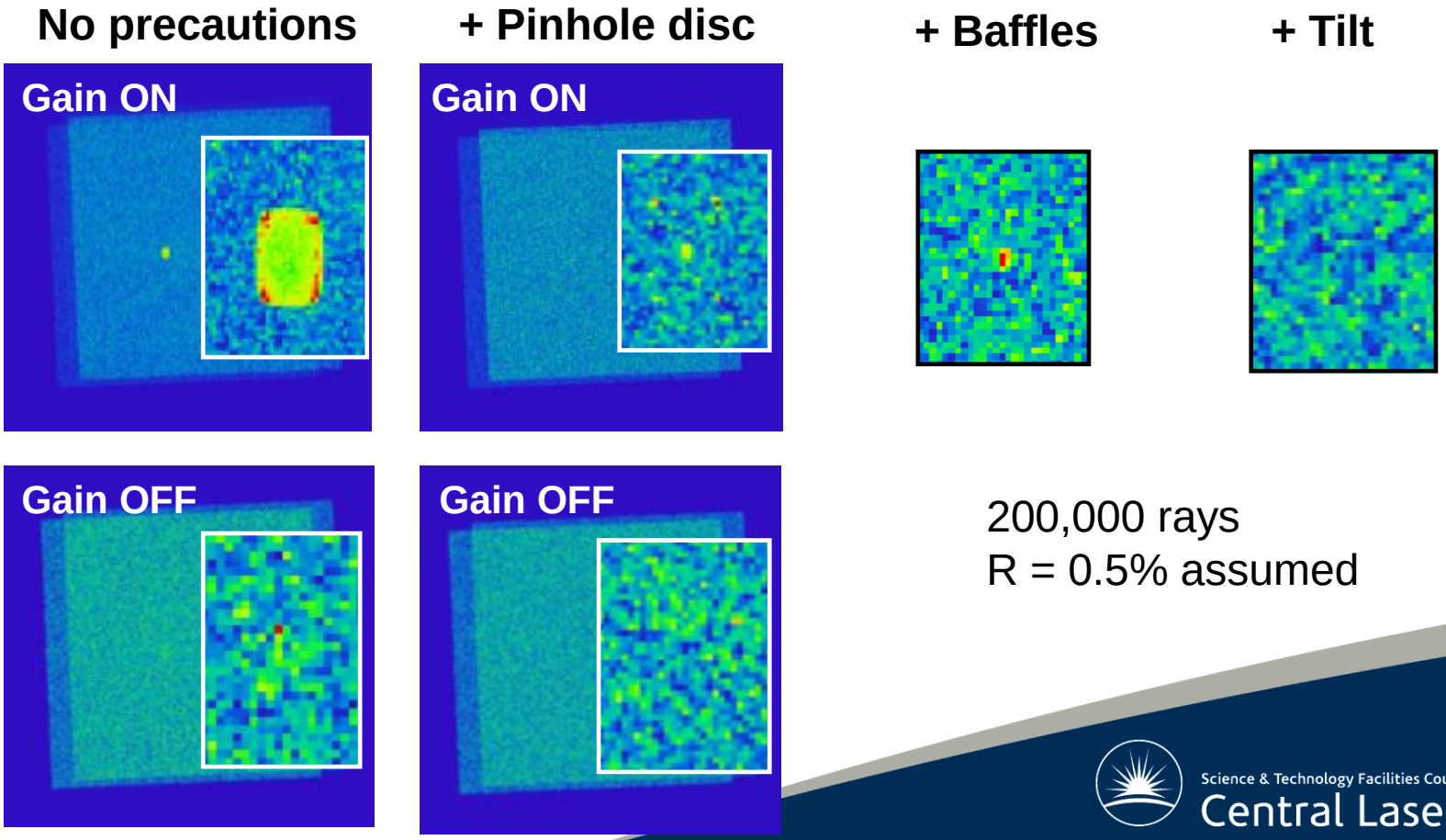
Observation (unpumped)
behind turning mirror D

ZEMAX prediction with Gain



Prevention of ~1.5 m Ghost Focus in AMP

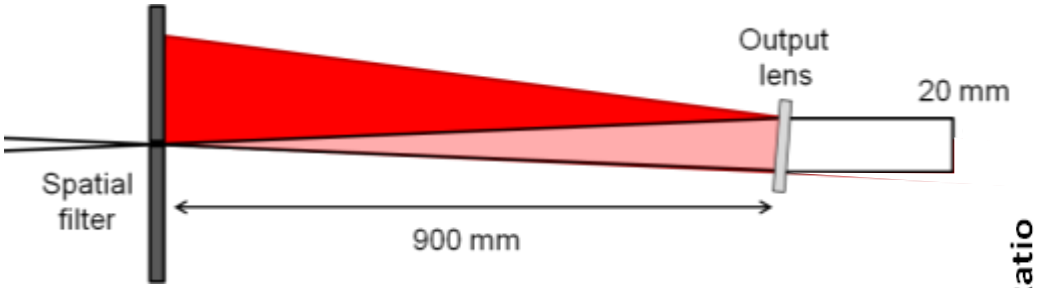
- Correct choice of pinhole size
- Baffling inside VSF to prevent cross talk between telescopes
- Telescope lens tilted to prevent pencil beams



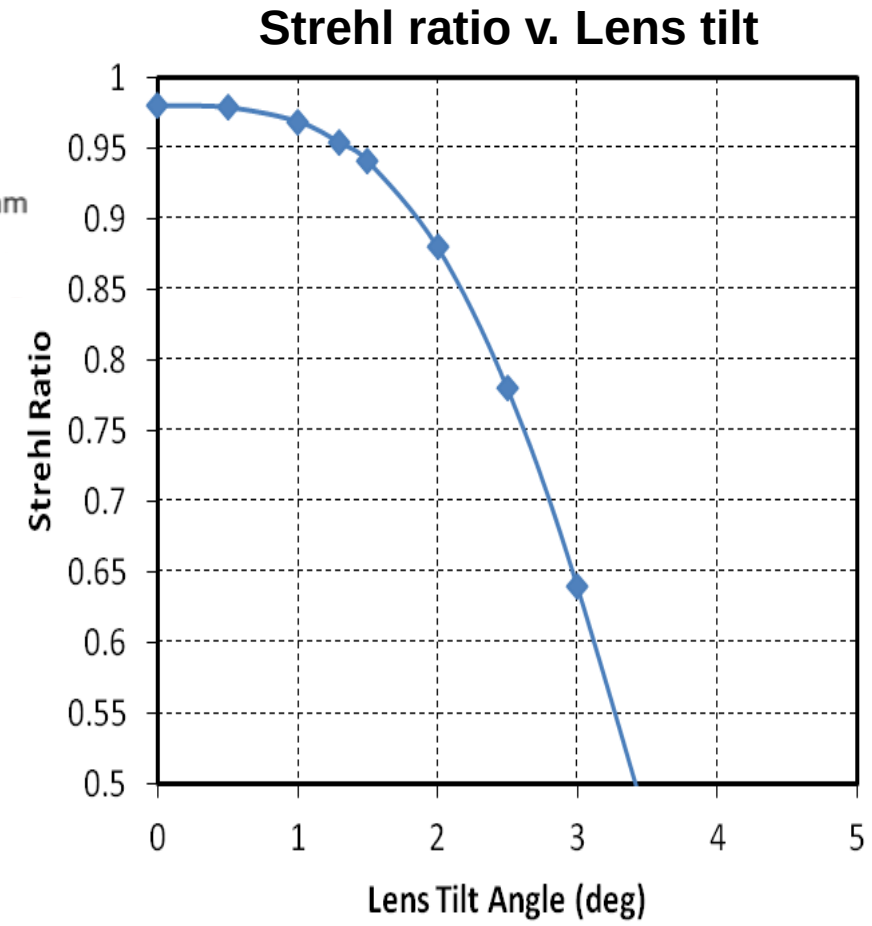
200,000 rays
R = 0.5% assumed

Effect of Lens Tilt on Image Quality

- Tilt angle required 0.7 deg



- Lens tilt minimal impact on image quality



Conclusions

- A novel multi-pass extraction architecture has been devised for DiPOLE prototype amplifier
  - System constraints (space, spatial & polarisation)
  - Angular multiplexing geometry allows up to 8 passes
- ZEMAX models have been used to design system
  - Optimum optical setup (geometry, pinhole sizes etc.)
  - Ghost & stray light analysis
- Multi-pass system built, installed & aligned for up to 8-passes
- Testing successfully demonstrated 10 J from 6-passes at 150 K
  - Optical-to-optical efficiency of ~25%

Any Questions?